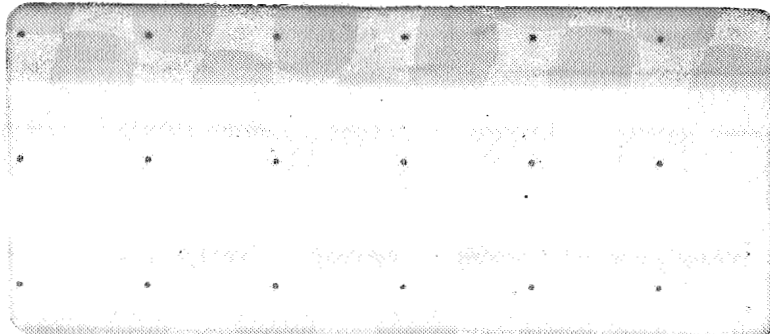


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MARS '71
TECHNICAL STUDY

EPD 427, Add. 1 12 December 1966

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FOREWORD

A one-week study, supplemental to EPD 427, was conducted in the Fall of 1966 to explore possible improvements in the 1971 Mariner lander mission. Results are contained in this report. Due to the short time scale on which this work was conducted, the reader must realize that in some areas the results are somewhat speculative and based on engineering judgment, but in general, the report indicates the classes of additional capability which can be realized.

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SUMMARY

The landed payload described in EPD 427 is a 45-lb, rough lander, with a post-landed lifetime of 1 hr, and has the capability to measure surface pressure and temperature. Improvement of the science capability of the design requires that some additional weight be made available to the science subsystem, and depending on the additional instruments considered, some other support functions must be provided. Included are communications, orientation and erection, thermal control.

The present design, as in EPD 427, has 13 lb allocated to the battery and assumes a specific energy of 4.5 whr/lb. Using a more recent and presently realistic battery performancy estimate of 15 whr/lb, approximately 9 lb of useful weight is available. Methods of using this weight to improve the mission capability were studied, and the results are discussed in this report.

Three alternate experiments have been considered: an environmental, a life detection, and a composition experiment. A weight breakdown and power profile for each of these experiments is presented in this report. These payloads are indicative of the class of experiment which can be performed in 1971 on the surface of the planet.

In summary, the study exemplifies how some very attractive scientific experiments can be performed with a total landed weight of 45 lb.

SECTION I

INTRODUCTION

During the summer of 1966, a three-week study was conducted of a Mars flyby and capsule mission for the 1971 launch opportunity. That study developed a 1971 mission, which was documented in EPD 427, "Mars '71 Technical Study", 15 August 1966. The capsule described performed both an entry mission and a landed mission. The landed mission was capable of performing surface pressure and temperature measurements, and had a 1-hr surface operating lifetime.

This supplement discusses some of the potential performance improvements to the landed payload of the Mariner 1971 Mars mission, as described in EPD 427. It is assumed that the reader of this report is familiar with the mission concept as described in that document. The atmospheric entry, terminal condition, and total landed weight used here are identical to those used in EPD 427. The design criteria, philosophy, and the atmosphere models are also consistent.

SECTION II

SYSTEM DESIGN

A. LANDER DESCRIPTION

The lander, as described in EPD 427, is mechanized to be as independent of the entry portion of the mission as practical. The lander receives power from the spacecraft for battery charging during the interplanetary cruise. The lander receives commands from the entry capsule, one 15 min before entry to initiate turn on, and another for the parachute initiation and release. Upon deployment from the entry capsule, the parachute extracts the lander out of the entry capsule. The lander then descends to the surface.

After landing, the lander continues to transmit scientific and engineering data to Earth. The lander antenna system consists of six wide-beam antennas located on the face of a cube with data sequentially transmitted over each antenna. The system does not require any post-landing antenna erection mechanism or other mechanical deployment. The lander lifetime is 1 hr, with a design goal of 2 hr.

The lander weight breakdown is shown in Table 2-1. The lander power requirements are outlined in Table 2-2.

Table 2-1. The Lander Weight Breakdown

LANDER	
Crushable Structure	7.0
Cover	2.0
Radio	3.0
Antennas	5.0
Data Handling	2.0
Sequencer and Switches	1.5
Battery	13.0
Power Switching and Logic	2.0
Structure	6.5
Cabling	1.0
Landed Science Payload	<u>2.0</u>
Total Weight	45 lb

Table 2-2. The Lander Power Requirements

Characteristics	E -15 to E +5	L +0 to L +60
Lander Data Handling, w	2.0	2.0
Lander Direct Radio, w	32.0	32.0
Lander Sequencer, w	0.5	0.5
Total User Power, w	35.0	35.0
Total Battery Power, w	43.8	43.8
Battery Capacity, w-hr	14.6	43.8
Total Battery Capacity, w-hr	58.4	

B. LANDING SITE LOCATION

The actual landing site location on the surface of the planet is determined by the direction of the approach asymptote, the entry angle, and the actual atmosphere encountered. Table 2-3 provides the values of range angles for the three arrival dates, the high- and low-surface pressure, and the nominal entry angle with its 3σ dispersion. The range angle is the planet centered angle from the sub-Earth point to the landing point.

Table 2-3. Landing Site Location

Entry Angle, θ_e	Arrival Date, 1971					
	Oct. 19		Oct. 29		Nov. 8	
	Range Angle, ϵ					
	5 mb	20 mb	5 mb	20 mb	5 mb	20 mb
50° (3 σ low)	55°	61°	50°	56°	43°	49°
55° (nominal)	49°	55°	44°	50°	47°	43°
60° (3 σ high)	43°	49°	38°	44°	31°	37°

Figures 2-1 and 2-2 illustrate the general locations of the landing sites with respect to the Sun, the Earth, and the planet terminator. The landings close to the sub-solar point have pre-entry relay geometry compatible with a Sun-side spacecraft flyby. These landing sites allow only a few hours of surface operations before the Earth sets as viewed from the landing site. Since the life detection experiment requires approximately 8-hr operational time, it is desirable to have the capability to either survive the night or to land close to the morning terminator as shown in Fig. 2-2. The landing sites shown in Fig. 2-2 require a dark-side flyby spacecraft in order to provide good relay geometry. The relay geometry has a major effect on the communication subsystem design.

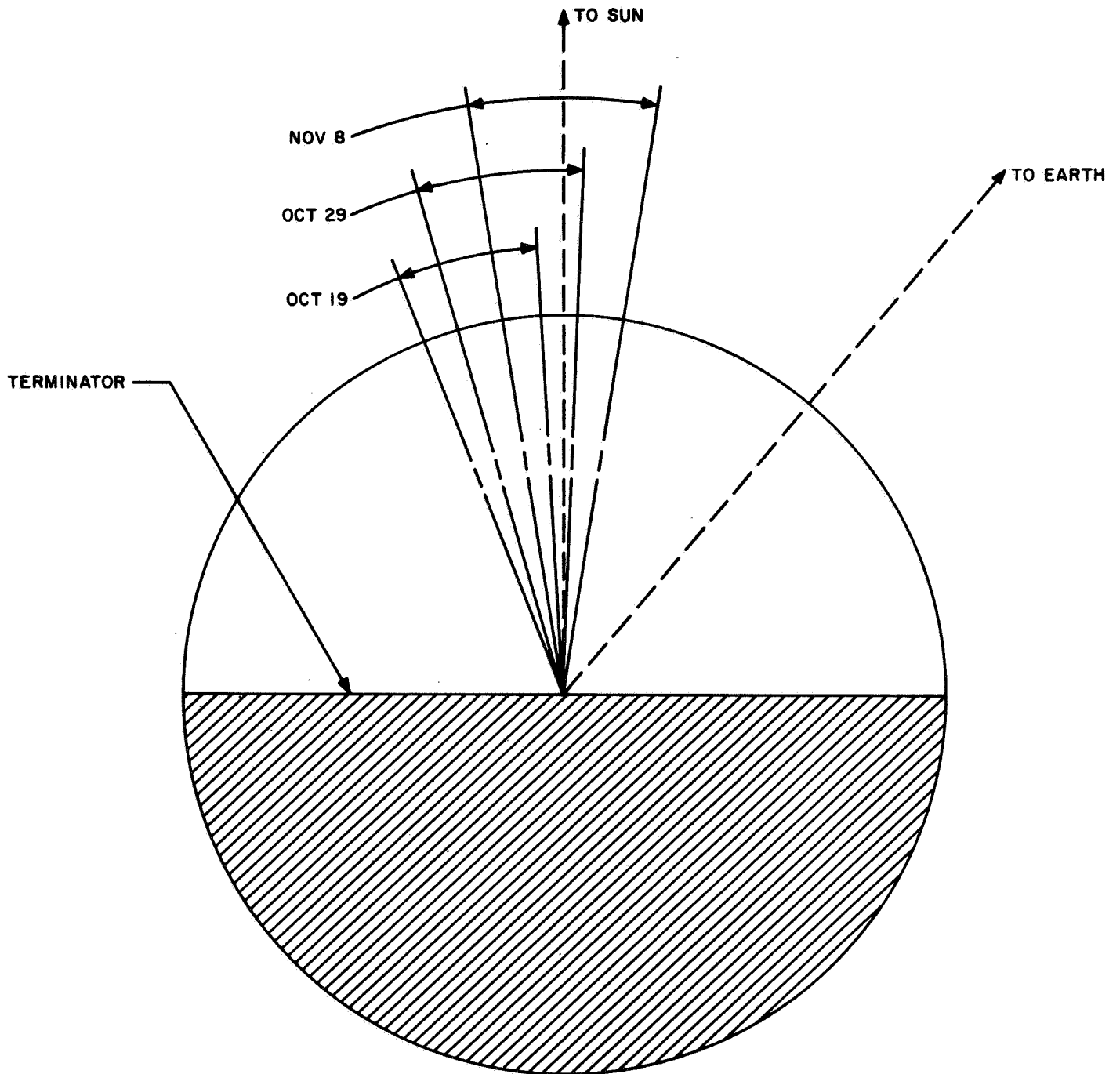


Fig. 2-1. Sun-Side Flyby Landings

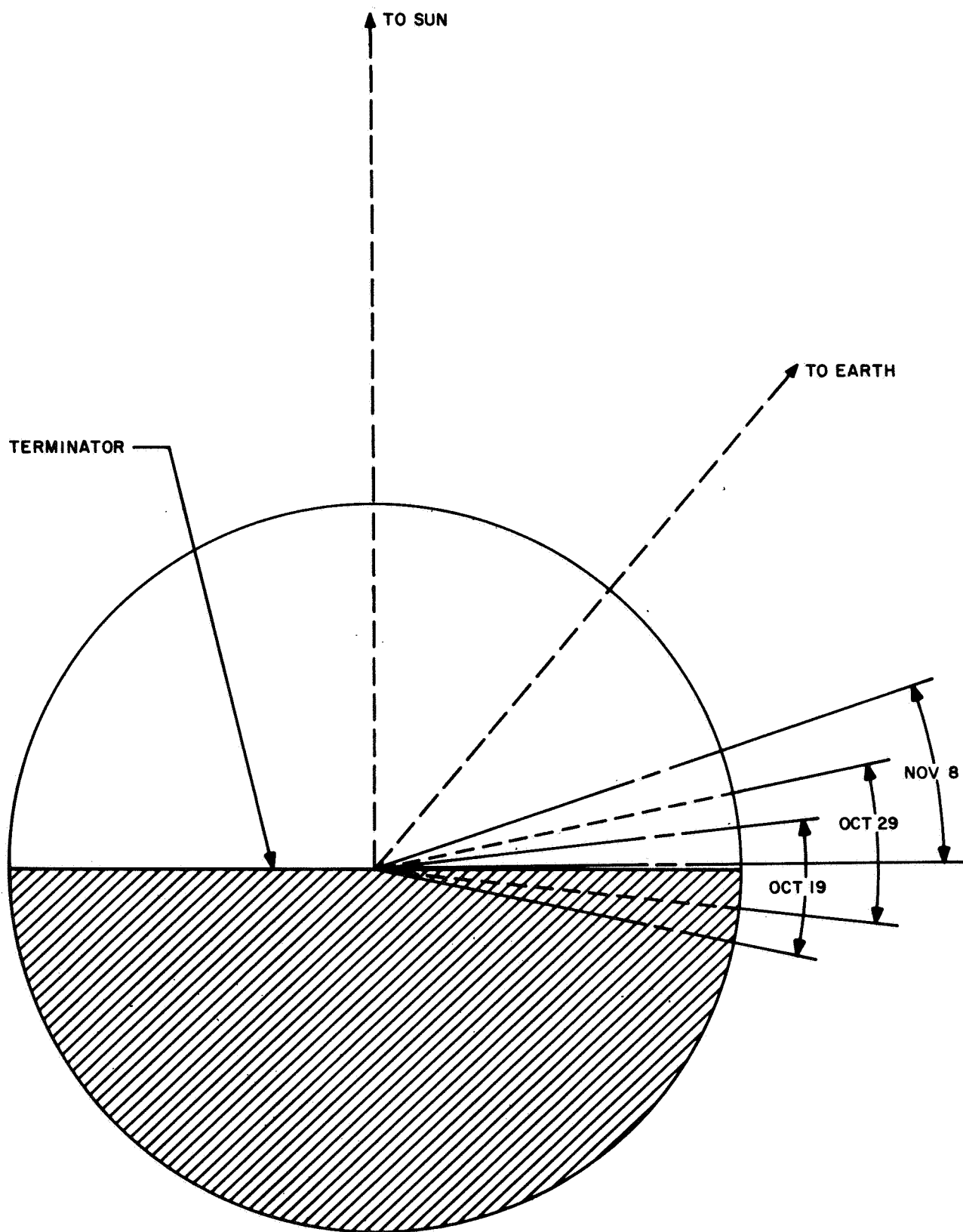


Fig. 2-2. Dark-Side Flyby Landings

Significant changes in the relay geometry require a detailed re-evaluation of the relay communication subsystem. Since the prime attention of this study was on the landed payload, it was decided to maintain a constant relay geometry and assume that the morning terminator landings require a dark side flyby spacecraft. While this assumption is somewhat arbitrary, it does provide a method to perform a morning terminator landing without completely invalidating the relay design as described in EPD 427.

C. LANDER CONFIGURATION

The following three lander configurations have been hypothesized and are typical of the types of landed missions which could be performed by changing the batteries from NiCd to AgZn. Testing and development work conducted since last summer now indicates that AgZn batteries with specific energies of 15 w-hr/lb can be made available for the 1971 Mars mission (refer to chapter IV). This improvement in battery performance will allow a weight reduction of approximately 9 lb in the power subsystem. The following lander systems exemplify how the weight can be used:

1) Life Detection Experiment. A life detection experiment of the Gulliver type pressure and temperature measurements can be performed. A weight breakdown is provided in Table 2-4 and the power requirements in Table 2-5.

The life detection experiment requires 8-hr surface operating time. This can be accomplished by either a morning terminator landing or daytime landing with the addition of nighttime survival and some additional operational and data transmission sequencing. A thermal control scheme can be mechanized using 2.6 lb of the 2.9 lb of system reserve to survive the night. In order to perform the life detection experiment, it is necessary to remove the impact limitier and eject four "sticky" strings. The strings are then brought back into the lander sphere to perform the experiment. The configuration is conceptually shown in Fig. 2-3.

2) Environmental Experiment. A weight breakdown of the configuration is provided in Table 2-6 and the power requirement in Table 2-7. In this experiment, measurements are made of pressure, temperature, wind, sub-surface water, oxygen and the local gravity.

Table 2-4. Life Detection Experiment, Weight Breakdown

Crushable Structure	7.0
Cover	2.0
Radio	3.0
Antennas	5.0
Data Handling	2.0
Sequencer and Switches	1.2
Battery	5.0
Power Switching and Logic	0.9
Structure	6.5
Cabling	1.0
Entry Accelerometer	0.4
Pressure and Temperature Probes	2.0
Limiter Removal	2.1
Life Detection Experiment	4.0
System Reserve	<u>2.9</u>
Total Weight	45.0 lb

Table 2-5. Life Detection Experiment, Power Requirement

	E -15 to E +5 (min)	L +0 to L +60 (min)
Pressure and Temperature Probes, w	---	1.0
Life Detector (Gulliver), w	---	2.0
Data Handling, w	2.0	2.0
Direct Radio, w	32.0	32.0
Sequencer, w	0.5	0.5
Pyro, w	---	<u>0.5</u>
Total User Power, w	34.5	38.0
Total Battery Power, w	43.0	47.5
Battery Capacity, w-hr	14.3	47.5
Total Battery Capacity, w-hr	61.8	
Total Battery Weight, lb	5.0	

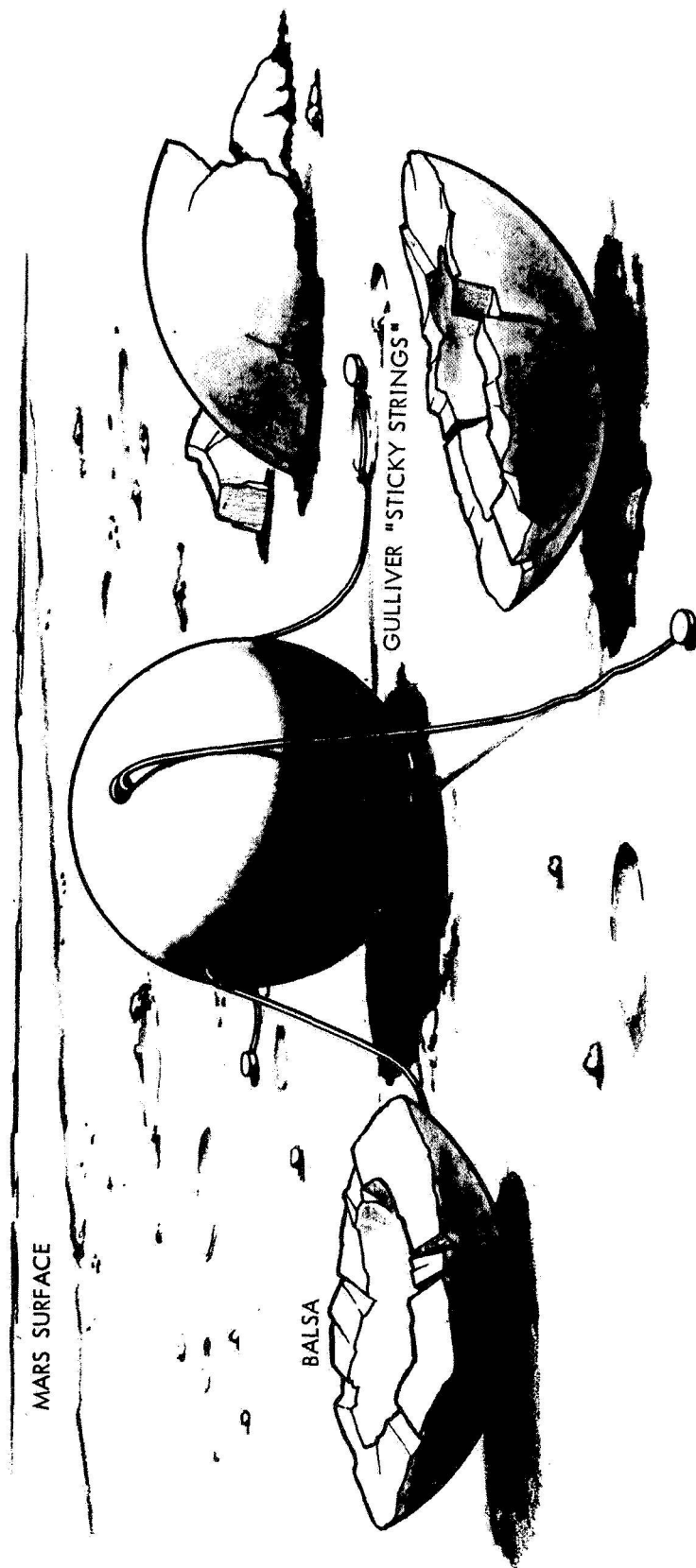


Figure 2-3. Life Detection Experiment

Table 2-6. Environmental Experiment, Weight Breakdown

Crushable Structure	7.0
Cover	2.0
Radio	3.0
Antennas	5.0
Sequencer and Switches	1.2
Battery	5.4
Power Switching Logic	0.9
Structure	6.5
Cabling	1.0
Entry Accelerometer	0.4
Pressure and Temperature Probes	2.0
Orientation	2.5
Limiter Removal	2.1
Instrument Boom	0.5
Wind Instrument	0.5
Water Instrument	1.7
Oxygen Instrument	1.3
Gravimeter	1.0
Data Handling	<u>1.0</u>
Total Weight	45.0 lb

Table 2-7. Environmental Experiment, Power Requirements

	E -15 to E +5 (min)	L +0 to L +60 (min)
Pressure and Temperature Probes, w	---	1.0
Wind Instrument, w	---	1.0
Water Instrument, w	---	1.0
Oxygen Instrument, w	---	2.0
Gravimeter, w	---	2.0
Data Handling, w	2.0	2.0
Direct Radio, w	32.0	32.0
Sequencer, w	0.5	0.5
Pyro, w	---	0.5
Total User Power, w	34.5	42.0
Total Battery Power, w	43.0	52.5
Battery Capacity, w-hr	14.3	52.5
Total Battery Capacity, w-hr	66.8	
Total Battery Weight, lb	5.4	

This experiment is compatible with the daytime landings and can perform all of the experiments within 1 hr after landing. After landing, the impact limiter is removed, and a leaf-spring orientation mechanism places the package in a predictable orientation with respect to the local surface. The instrument boom is erected to approximately 2 m above the sphere to accommodate the wind measurement (see Fig. 2-4). The six-antenna array is still used to allow the other experiment to be made in the event of an orientation failure.

3) Composition Experiment. This experiment is compatible with the daytime landing and does not require any impact limiter removal or erection mechanism (see Fig. 2-5). A weight breakdown of this experiment is provided in Table 2-8 and a power requirement in Table 2-9.

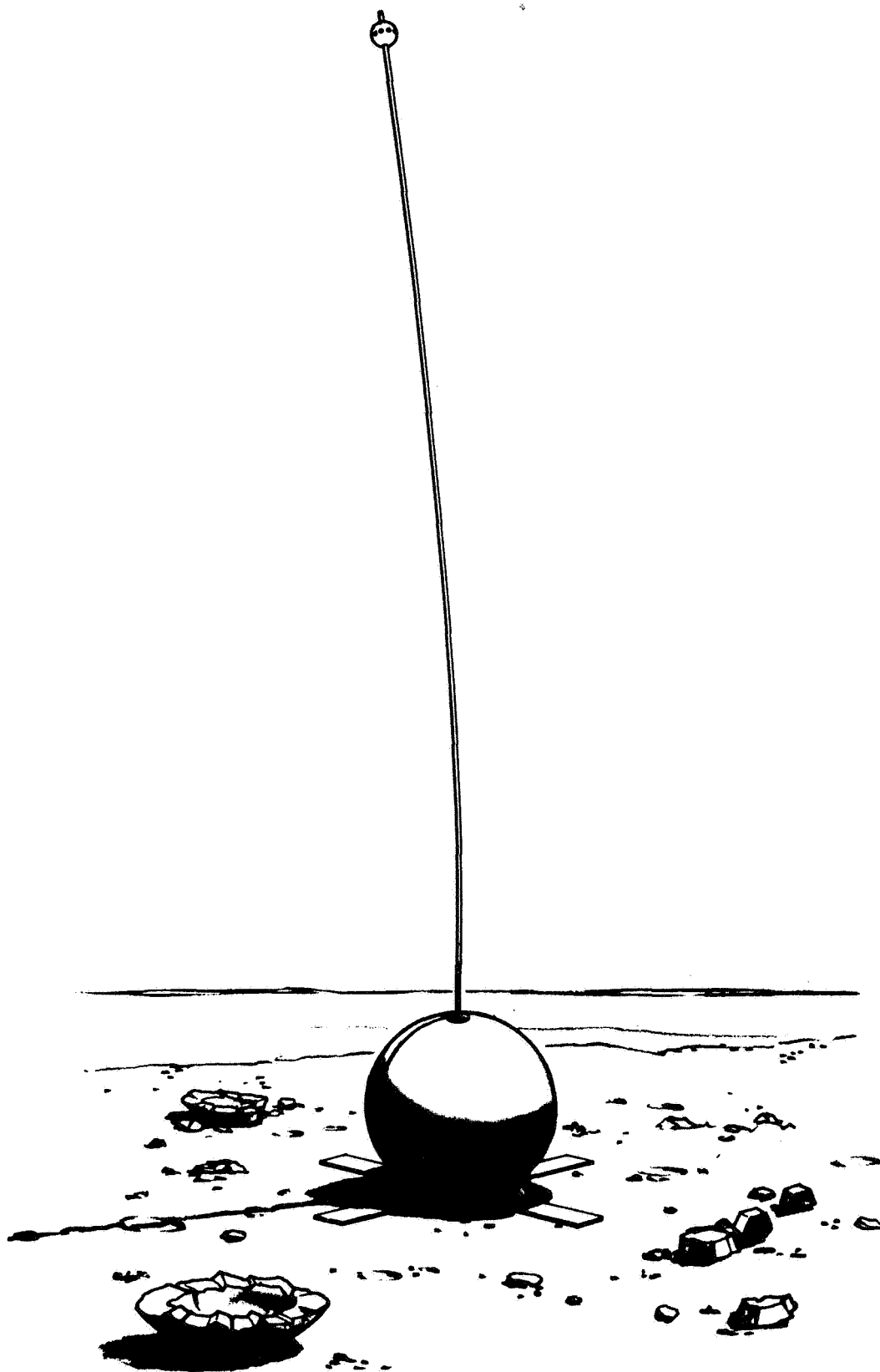


Fig. 2-4. Environmental Experiment

Table 2-8. Composition Experiment, Weight Breakdown

Crushable Structure	7.0
Cover	2.0
Radio	3.0
Antennas	5.0
Sequencer and Switches	1.2
Battery	5.4
Power Switching and Logic	0.9
Structure	6.5
Cabling	1.0
Entry Accelerometer	0.4
Pressure and Temperature Probes	2.0
Composition Measurement	8.0
Data Handling	2.0
System Reserve	<u>0.6</u>
Total Weight	45.0 lb

Table 2-9. Composition Experiment, Power Requirements

	E -15 to E +5 (min)	L +0 to L +60 (min)
Pressure and Temperature Probes, w	---	1.0
Composition Measurement, w	---	6.0
Data Handling, w	2.0	2.0
Direct Radio, w	32.0	32.0
Sequencer, w	0.5	0.5
Pyro, w	---	0.5
Total User Power, w	34.5	42.0
Total Battery Power, w	43.0	52.5
Battery Capacity, w-hr	14.3	52.5
Total Battery Capacity, w-hr	66.8	
Total Battery Weight, lb	5.4	

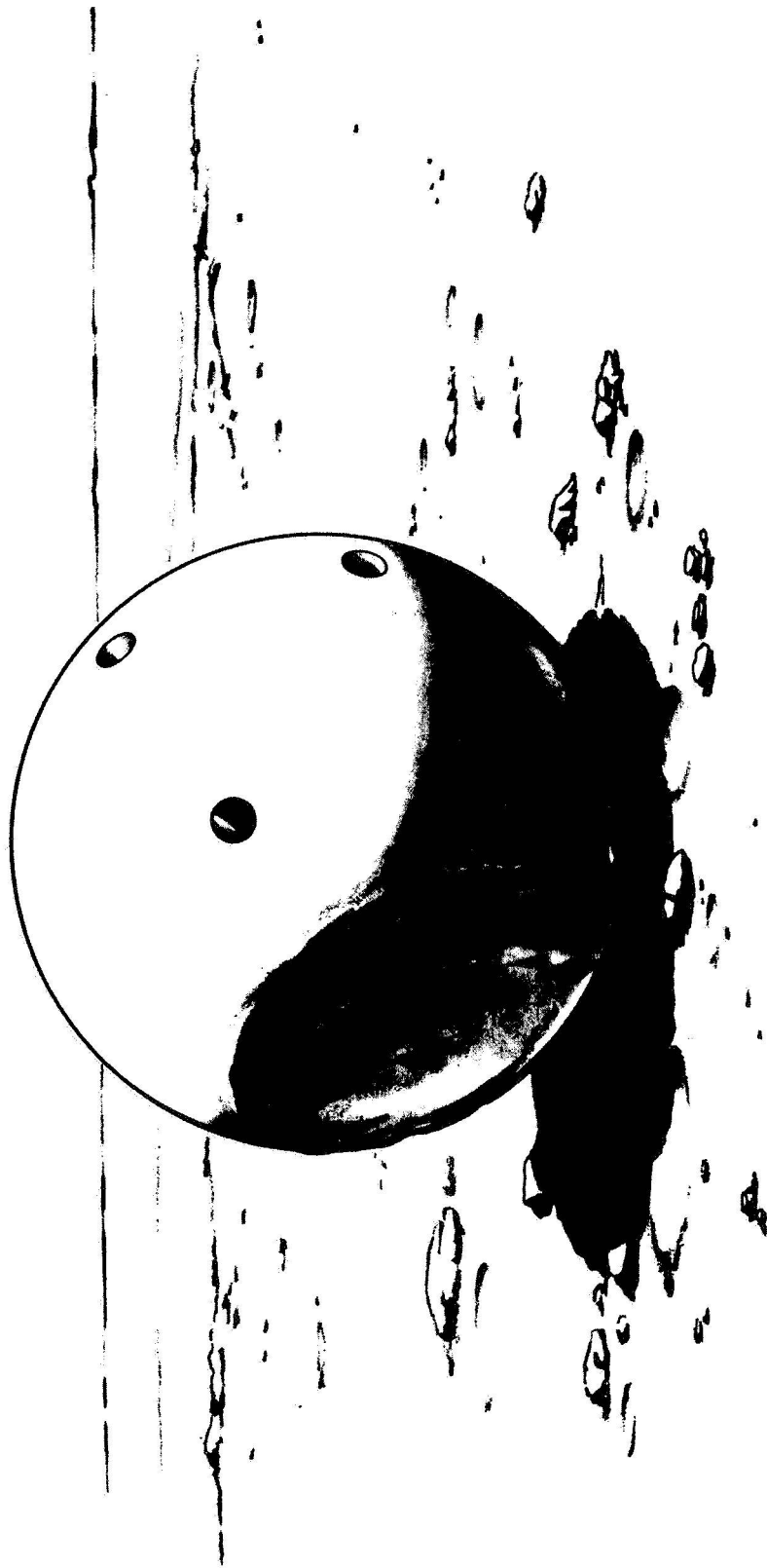


Figure 2-5. Composition Experiment

SECTION III

SCIENCE SUBSYSTEM

A brief study has been conducted to develop possible experiments for a 1971 Mars lander. For the most part, the instruments listed are considered strictly from a feasibility point of view, and therefore, the weights are best estimates.

The experiments considered are divided into three groups. Each group includes a major experiment or requires orientation and erection which precluded combinations of the major experiments. All three groups include surface pressure and temperature measurements because of the fundamental nature of such measurements and because the relatively small weight involved. There are many other combinations possible; however, for the purposes of this discussion, it is convenient to restrict consideration to the three options listed as follows:

a) Life Detection			
		<u>Weight (lb)</u>	<u>Power (w)</u>
1)	Gulliver	2.0 - 4.0	2.0
2)	Pressure	1.0	0.5
3)	Temperature	1.0	0.5
4)	Data Handling	2.0	2.0
b) Environmental			
1)	Wind (inc mast)	1.0	1.0
2)	Pressure	1.0	0.5
3)	Temperature	1.0	0.5
4)	Surface Water	1.7	1.0
5)	Gravimeter	1.0	0.5
6)	Oxygen	1.3	2.0
7)	Data Handling	1.0	2.0

c)	Atmospheric Analysis	<u>Weight (lb)</u>	<u>Power (w)</u>
1)	Mass Spectrometer or Gas Chromatograph	8.0 - 6.0	5.0 - 6.0
2)	Pressure	1.0	0.5
3)	Temperature	1.0	0.5
4)	Data Handling	2.0	2.0

A. LIFE DETECTION EXPERIMENT

This option represents an attempt to make a direct biological test for Martian life at the earliest possible opportunity. An experiment of this type in 1971 would advance by several years the opportunity to make such measurements. The probability of planet contamination will be less in 1971 than in 1973 or later and, in fact, such measurements, at an early date, may be instrumental in determining whether the planet becomes contaminated later.

The instrumentation considered for the life detection measurement is a version of the Gulliver. The sample collection is mechanized through the deployment and retrieval of "sticky strings." A radioactively labeled nutrient is applied to the sample and growth is monitored by searching for the label in the gaseous products of the metabolic process. A control culture in which the growth is intentionally halted is also monitored for comparison. The culture must be allowed a substantial growth period of at least eight hours to assure detection. Communication need not be maintained during the growth period; however, periodic sampling of the culture growth must be made, and the culture temperature must be maintained above freezing. The total data required is

consistent with EPD 427. Impact limiter removal will be required to provide access for sample collection.

B. ENVIRONMENTAL EXPERIMENT

Substantial information relating to the micrometeorology of Mars can be obtained with measurement of pressure, temperature and wind. The extension of this data to wider regions of the planet is predicated on large scale modeling. Such models would be required to be consistent with the direct measurements. The meaningful measurement of the surface wind gradient requires the deployment of a short mast (approximately 2 m). Orientation of the lander system is, therefore, required.

Subsurface water measurements are considered important because of the Earth life dependence on water. The presence of water on Mars is considered important as a guide to determine the most likely location of Martian life. With an erected system it is considered feasible to insert a small probe into the surface to detect water vapor.

Oxygen and gravity measurements are included as somewhat lower priority experiments. Although the oxygen measurement will provide a direct test of oxygen at the surface, there is a fair chance that Earth-based measurements will be capable of determining the overall oxygen concentration. The gravity device is intended to provide the basis for surface elevation measurement at the landing site. This data would be valuable in establishing a datum for topographic mapping.

C. ATMOSPHERIC ANALYSIS

The precision of the entry composition measurement does not permit a search for trace constituents which are important in understanding the detailed chemistry of the atmosphere. A precision surface composition measurement could provide increased sensitivity and at the same time provide an opportunity to detect gases near the surface which are diffused at the altitude where the

last sample for the entry measurement is taken. The sensitivity required for the measurement is parts per million and below.

Either a mass spectrometer or a gas chromatograph can provide sensitivities in the ppm range, and no distinction between the two is made at this time. Although a mass spectrometer is generally considered the more powerful instrument, the data constraint does not allow full utilization of its potential. Fairly sophisticated onboard data processing would be required to take full advantage of the transmitted data. Additional data processing weight is listed to account for the increased complexity.

SECTION IV

POWER SUBSYSTEM

The lander power subsystem described in EPD 427 has a source requirement of 58.4 w-hr at a discharge rate no greater than C rate and at an output voltage of 11 v. This requirement was satisfied with a Ni-Cd battery estimated at 13 lb and 172 in.³. In this study, new estimates have been developed for three possible sources:

- 1) Ni-Cd battery
- 2) Ag-Zn battery
- 3) RTG.

A. Ni-Cd BATTERY

The present status of the sterilizable Ni-Cd battery indicates that the weight and volume requirements will be 15 lb and 190 in³. These conclusions were obtained from a Ni-Cd cell test program in which testing was done under various regimes after sterilization. It was found that electrical performance on cycling for sterilized cells was different from that of non-sterilized controls in that the capacity of the sterilized cells started at a value well below the rate capacity and changed little during cycling; the capacity of control cells started at the rated value and decreased steadily to values generally below those of sterilized cells after 300 cycles. The evaluation of the cycling and failure data led to the above-defined battery weight and density.

B. Ag-Zn BATTERY

The design and fabrication of the heat sterilizable Ag-Zn battery requires the development of new materials and technology. Electro-chemistry, cell case, separator, and cell design studies have been undertaken to achieve this development. The studies have provided: (1) a new separator material which has functioned adequately after sterilization; (2) new case materials; (3) the data necessary for sterilizable cell pack design; (4) a modified Zn plate which

prevents the capacity loss previously experienced; (5) basic physical chemistry information; (6) new plate structure designs compatible with the high impact requirement. These developments have progressed to the point of testing sterilizable sealed cells. Based upon data for sterilized unsealed cells, the sealed sterilizable Ag-Zn battery should have a specific energy of 15 w-hr/lb and specific energy densities of 1 w-hr/in³. Using these performance numbers, the battery weight and volume are 3.9 lb and 58.4 in³, respectively. Using a battery weight increase of 20 percent for the landing environment, results in a battery weight of 4.7 lb.

C. RTG

Current RTG technology is such that in the 20 to 100 w range, the RTG's can deliver about 1 w/lb, excluding shielding. The weights of a 40- and a 60-w unit would thus be about 40 and 60 lb, respectively, assuming that a long-lived isotope such as Pu 238 is used. If a short-life isotope must be used because of fuel availability problems, these weights could increase significantly to accommodate a mechanism for rejecting the excess heat. If, alternatively, a long-lived isotope such as Pu 238 is used, the fuel availability problem becomes severe; the estimated lead times for establishing a processing facility and processing adequate amounts of the isotope are 4-5 years. These lead times do not appear compatible with a Mariner 1971 schedule.

Shielding considerations may also dictate a significant weight increase, particularly if a science package employing a radiation-measuring instrument is included. Survival of electronic components aboard the capsule could dictate a 50% or more increase in RTG weight for shielding; much more would be required for compatibility with radiation-sensing science instruments.

SECTION V

MECHANICAL CONFIGURATION

A. ORIENTATION METHOD

For science payloads requiring lander orientation prior to science deployment, a scheme has been devised based upon a concept developed in some previous Voyager lander studies. Following capsule rough landing, the impact limiting material is pyrotechnically removed by means of strands of explosive material imbedded in the impact limiting material. The weight of the removal mechanism is estimated to be 2.1 lb.

Following the impact limiter removal, an orientation mechanism drives a specific side of the survival sphere to an upright position. The mechanism consists of a set of leaf springs wrapped around the exterior of the lander and attached to the lander at a common point. Upon release, the leaf springs straighten, causing the lander to roll to an upright position. The mechanism has been sized to roll the lander up a 45 deg slope, such as the side wall of an impact crater. With the exception of the spring release latch, there is no internal protrusions which would interfere with the payload's internal packaging geometry. The weight for the orientation mechanism is estimated to be 2.5 lb.

B. ERECTION MECHANISM FOR THE WIND EXPERIMENT

The wind measurement requires erecting a 2-oz wind detector, two meters above the lander following impact limiter removal and lander orientation. Such a device could consist of a self-extendible mast of the DeHavilland type, weighing 0.5 lb and occupy 20 in.³. The device would be capable of sustaining Mars wind loads and would be erectible in the gravitational fields of both Mars and Earth.

SECTION VI

TEMPERATURE CONTROL

Table 6-1 presents weights for four schemes for maintaining lander electronics and battery temperatures above 40°F during Mars night. Schemes 1 and 2 do not use insulation; schemes 3 and 4 are based on 3 lb of Min K insulation (0.7 in. thick) attached to the lander exterior surface. In those cases which do not use an RTG, the most attractive plan is to make up night-heat losses by using a chemical reactor (Schemes 2 and 4). Insulation in conjunction with a chemical reactor reduces the reactor weight but results in an overall weight increase. A chemical reactor of the type conceived has not been built. Analytical feasibility has been established, and no insurmountable problems are anticipated.

Batteries supplying power for night survival at the rate of 15 w-hr/lb appear to be unreasonable in this application (Schemes 1 and 3).

Table 6-1. Schemes for Mars Night Survival and Weights in Pounds

Scheme	1	2	3	4
Insulation Weight	0	0	3.0	3.0
Battery Weight	130	0	39.0	0
Chemical Reactor Weight	<u>0</u>	<u>2.6</u>	<u>0</u>	<u>1.0</u>
Total Weight (lb)	130	2.6	42.0	4.0

Were the lander electrical power to be supplied by a 5 w, 5 percent efficient RTG unit, approximately 1.0 lb of local insulation would be required for thermal control in order to survive the night; however, during cruise when the lander is stowed within the capsule and the impact limiting material is in place, the removal of RTG heat will be a significant problem. At least 5 lb of

thermally conductive material will be required to remove this heat by a passive transport mechanism. More likely a fluid-loop scheme will be required.

To arrive at the conclusions discussed above, the following set of specific conditions and parameters were used in the analysis:

1)	Lander Diameter	13 in.
2)	External Surface Emittance	0.7
3)	Convective coefficient	0.8 btu/hr-ft sq-F
4)	Average Mars night Surface temp	-100°F
5)	Average Mars night atmosphere temp	-100°F
6)	Min K insulation density	14 lb/cu ft
7)	Min K insulation conductance	0.17 btu-in./hr ft sq-F
8)	Chemical reactor (Li-Cl)	1180 w-hr/lb reactants

SECTION VII

TELECOMMUNICATIONS

The communication link proposed in EPD 427 for the Mars 1971 lander transmits data via a capsule-to-Earth direct link at a 1.0 bit/sec rate using coded FSK communication system. To avoid any requirement for orienting an antenna, the mechanization proposed utilizes six antennas and sequentially transmits the same data over each antenna. This results in an effective data rate of 1/6 bit/sec. Sections A and B reports the results of an examination of two methods which could be used to reduce the number of antennas over which the same data must be transmitted and thus achieve a higher effective data rate.

A. ANTENNA SELECTION USING A COHERENT RECEIVER

One simple method of determining which antenna should be used is to incorporate into the capsule a receiver which can measure the received signal strength in each of the six antennas. By comparing the received signal power at each antenna, the proper antenna can be selected.

The mechanization considered uses a Mariner C type receiver with coherent AGC. Equipment must be added to the receiver to permit automatic acquisition. Upon landing, the receiver is switched to the first antenna, and the receiver frequency is swept to acquire the signal transmitted from earth. After the signal is acquired, the receiver AGC voltage is converted to digital form and stored. The same process is repeated for each of the six antennas. The transmitter is then switched to the antenna with highest AGC.

The APC receiver would be designed such that the RMS loop-phase error due to noise is less than 10 deg. Thus,

$$\sigma_{\phi n} \leq \frac{\pi}{18} \quad (1)$$

and 3σ noise peaks are less than 30 deg. The APC receiver would also be designed for a maximum peak phase error due to modulation of 15 deg. Thus,

$$\Delta_{\phi m} \leq \frac{\pi}{12} \quad (2)$$

Since

$$\sigma_{\phi n}^2 = \left(\frac{N}{S}\right)_{B_L} \quad \left(\frac{N}{S}\right)_{B_L} \ll 1 \quad (3)$$

where $(N/S)_{B_L}$ is the noise to signal ratio in the receiver APC loop noise bandwidth, to satisfy condition (2)

$$\left(\frac{S}{N}\right)_{B_L} \geq 15.16 \text{ db} \quad (4)$$

Table 7-1 shows that a margin which exceeds the sum of the negative tolerances can be maintained with a receiver having an APC loop noise bandwidth (B_L) of 100 cps. Assuming the APC loop is designed to have a 0.707 damping factor (ξ_L) at this operating point, the loop natural frequency is:

$$\omega_L = \frac{4\sqrt{2}}{3} B_L = 188.5 \text{ cps} \quad (5)$$

Since

$$\Delta_{\phi m} = 1.043 \frac{\dot{\omega}}{\omega_L} \quad \xi_L = 0.707 \quad (6)$$

the maximum rate at which the receiver frequency can be swept for acquisition is:

$$\dot{f}_{\max} = \frac{\pi}{12} \frac{1}{1.043} \frac{\omega_L^2}{2\pi} \quad (7)$$

Table 7-1. Telecommunication Design Control Table

	Value	Tolerance
Transmitter RF Power Output	80.0 dbm	---
Transmitting Circuit Loss	0.0 db	---
Transmitting Antenna Gain	53.0 db	± 0.5 db
Transmitting Antenna Pointing Loss	---	---
Space Loss, $R = 10^8_{\text{km}}$ $F = 2113_{\text{mc}}$	-258.94 db	---
Polarization Loss	---	± 0.05 db
Receiving Antenna Gain ^(a)	6.0 db	+1.0, -0.4 db
Receiving Antenna Pointing Loss ^(b)	-5.5 db	+5.5, -1.0 db
Receiving Circuit Loss ^(c)	-2.2 db	± 0.5 db
Received Carrier Power	-127.64 dbm	+7.55, -2.45 db
Receiving System Noise Spectral Density ($T_s = 1550^\circ\text{K}$)	-166.69 $\frac{\text{dbm}}{\text{cps}}$	+0.5, -1.0 db
Carrier APC Loop Noise Bandwidth $B_L = 100 \text{ cps} \pm 15 \text{ cps}$	20.00 db cps	+0.61, -0.71 db
Required SNR	15.16 db	---
Threshold Carrier Power	-131.53 dbm	+1.11, -1.71 db
Margin	3.89 db	+9.26, -3.56 db
Notes: a) No balsawood covering b) For 54.6 deg pointing error c) Includes 0.4 db ± 0.1 db diplexer loss		

or, using equation (5)

$$(\dot{f})_{\max} = \frac{(188.5)^2}{24 \times 1.043} \text{ cps/sec} = 1.42 \text{ kc/sec}$$

Thus, assuming a receiver center frequency stability of ± 3 ppm, a band of width

$$\Delta f = (2) (2113 \times 10^6) \cdot (3 \times 10^{-6}) = 12.678 \text{ kc}$$

must be searched during acquisition. The time to sweep the frequency band is

$$T_s = \frac{12.678}{1.42} \text{ sec} = 9.0 \text{ sec}$$

Therefore, allowing two sweeps per antenna, acquisition should take a maximum of 108 sec. Operational problems might significantly increase acquisition time. Acquisition could be reinitiated by ground control at any time, by using the APC receiver loss of lock to start the acquisition sweep and antenna search.

The system would increase the effective data rate to approximately 1 bps at the cost of some additional risk that no data would be obtained.

A weight and power summary for the option is included in Table 7-2.

Table 7-2. Antenna Selection Using a Coherent Receiver

	Weight (lb)	Power (watt)
Diplexer	1.0	---
Receiver	7.4	6.5
A-D Converter	0.2	1.2
Programmer	<u>0.3</u>	<u>2.0</u>
Total	8.9	9.7

In summary, an antenna selection scheme using a coherent receiver appears feasible at a cost of 8.9 lb of additional capsule equipment and 9.7 w of power. Initial acquisition would require 108 sec.

B. ANTENNA SELECTION USING A GRAVITY SENSOR

After a preliminary examination, use of a gravity sensor to reduce the number of antennas through which data must be transmitted was discarded. For capsule orientation with one antenna nearly vertical, five antennas were necessary to provide the required coverage. It was felt that elimination of transmission through one antenna and the resultant 20% increase in effective data rate would not justify the complexity involved.